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# Total Productive Maintenance: The Evolution in Maintenance and Efficiency

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**ABSTRACT**
The purpose of this paper is to evaluate the contributions of total productive maintenance (TPM) initiatives towards improving manufacturing performance at Shalimar Nutrients Private Limited (SNPL) Nagpur.The correlations between various TPM implementation dimensions and manufacturing performance improvements have been evaluated and validated by employing overall equipment effectiveness (OEE) in Maintenance Department. The research focuses upon the significant contributions of TPM implementation success factors like top management leadership and involvement, traditional maintenance practices and holistic TPM implementation initiatives, towards affecting improvements in manufacturing performance in the SNPL. The study establishes that focused TPM implementation over a reasonable time period can strategically contribute towards realization of significant manufacturing performance enhancements. The study highlights the strong potential of TPM implementation initiatives in affecting organizational performance improvements. The achievements of SNPL manufacturing organizations through proactive TPM initiatives have been evaluated and critical TPM success factors identified for enhancing the effectiveness of TPM implementation programs in the SNPL context.

***Keywords***: Total productive maintenance, Preventive maintenance, Overall equipment efficiency

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## I. INTRODUCTION

TPM is a unique Japanese philosophy, which has been developed based on the productive maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971. Total productive maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce. The manufacturing industry has experienced an unprecedented degree of change in the last three decades, involving drastic changes in management approaches, product and process technologies, customer expectations, supplier attitudes as well as competitive behaviour. In today's fast changing marketplace, slow, steady improvements in manufacturing operations do not guarantee sustained profitability or survival of an organization. Thus the organizations need to improve at a faster rate than their competitors, if they are to become or remain leaders in the industry.

## II. TPM – EVOLUTION

TQM is defined by Feigenbaum as both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organization. It is the application of quantitative methods and involvement of people to improve all the processes within an organization and to exceed customer needs.

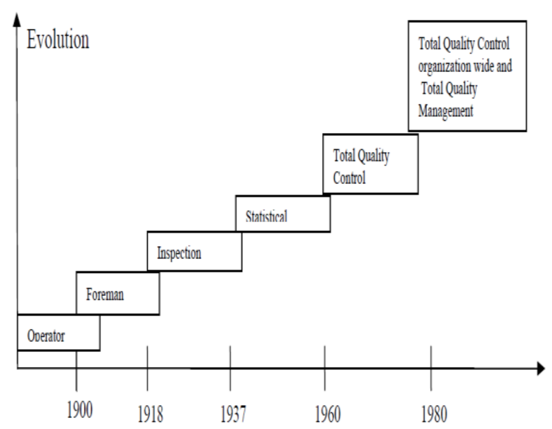


**Figure 1: Historical evolution of quality methods**

## III. TPM PILLARS


**Figure 2: The traditional TPM model consists of a 5S foundation and eight supporting activities**

The eight pillars of TPM are mostly focused on proactive and preventative techniques for improving equipment reliability.

**1.1 Autonomous Maintenance**

It places responsibility for routine maintenance such as cleaning, lubricating, and inspection, in the hands of operators.Train the operators to close the gap between them and the maintenance staff, making it easier for both to work as one team. Change the equipment so the operator can identify any abnormal conditions and measure deterioration before it affects the process or leads to a failure.The following seven steps are implemented to progressively increase operator's knowledge, participation and responsibility for their equipment.

1. Perform initial cleaning and inspection
2. Countermeasures for the causes and effects of dirt and dust
3. Establish cleaning and lubrication standards
4. Conduct general inspection training
5. Carry out equipment inspection checks
6. Workplace management and control
7. Continuous improvement

It gives operators greater "ownership" of their equipment, increases operators' knowledge of their equipment, ensures equipment is well-cleaned and lubricated, identifies emergent issues before they become failures, frees maintenance personnel for higher-level tasks.

1.2 Planned Maintenance

It establishespreventative and predictive maintenance systems for equipment and tooling. The following seven steps are implemented under the planned maintenance.

1. Correct operation
2. Correct set-up
3. Cleaning
4. Lubrication
5. Retightening
6. Feedback and repair of minor defects
7. Quality spare parts

It significantly reduces instances of unplanned stop time and enables most maintenance to be planned for times when equipment is not scheduled for production thereby reduces inventory through better control of wear-prone and failure-prone parts.

1.3 Quality Maintenance

It is designed for error detection and prevention into production processes. It applies root cause analysis to eliminate recurring sources of quality defects.It specifically targets quality issues with improvement projects focused on removing root sources of defects and hence reduces number of defects. It reduces cost by catching defects early (it is expensive and unreliable to find defects through inspection).

1.4 Focused Improvement

Maximize efficiency by eliminating waste and manufacturing losses. Manufacturing losses are categorized into 3 big losses:

1) Equipment losses
2) Manpower losses
3) Material losses

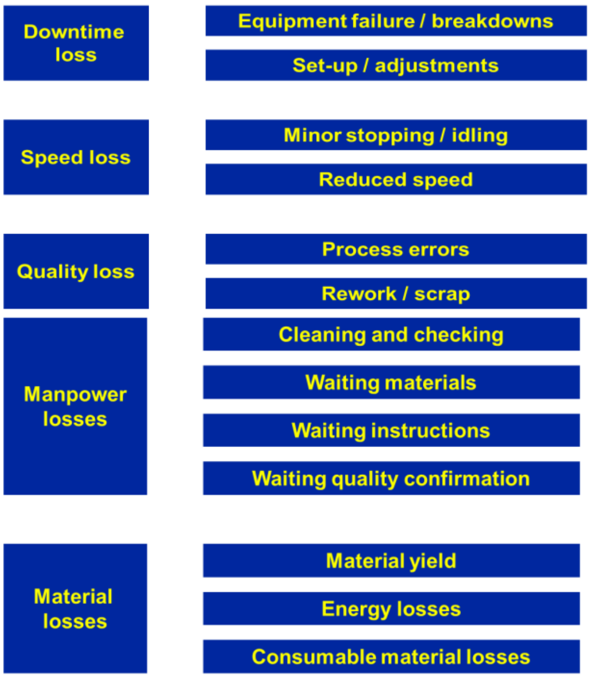


**Figure 3: Manufacturing losses**

1.5 Early Equipment Management

It is directs practical knowledge and understanding of manufacturing equipment gained through TPM towards improving the design of new equipment.

New equipment needs to be:

1) easy to operate
2) easy to clean
3) easy to maintain and reliable
4) have quick set-up times
5) operate at the lowest life cycle cost

1.6 Training and Education

It fills in knowledge gaps necessary to achieve TPM goals. It applies to operators, maintenance personnel and managers.Operators develop skills to routinely maintain equipment and identify emerging problems.Maintenance personnel learn techniques for proactive and preventative maintenance.Managers are trained on TPM principles as well as on employee coaching and development.

1.7 Safety, Health, Environment

It maintains a safe and healthy working environment. It eeliminates potential health and safety risks, resulting in a safer workplace and specifically targets the goal of an accident-free workplace.

1.8 TPM in administrative and support departments

Administrative and support departments can be seen as process plants whose principal tasks are to collect, process, and distribute information. It helps to eextends TPM benefits beyond the plant floor by addressing waste in administrative functions.

## IV. S PHILOSOPHY

TPM starts with 5S. It is a systematic process of housekeeping to achieve a serene environment in the work place involving the employees with a commitment to sincerely implement and practice housekeeping. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement. 5S is foundation program before theimplementation of TPM.

**Table 1: 5 S principles**

| Japanese nomenclature (English 5S/5C): Features |
|---|
| Seiri (Sort/Clear): Sort out unnecessary items from the workplace and discard them. |
| Seiton (Set in order/Configure): Arrange necessary items in good order so that they can be easily picked up for use. |
| Seisio (Shine/Clean and check): Clean the workplace completely to make it free from dust, dirt and clutter |
| Seiketsu (Standardize/Conformity): Maintain high standard of housekeeping and workplace organization |
| Shitsuke (Sustain/Custom and practice): Train and motivate people to follow good housekeeping disciplines autonomously |

If this 5S is not taken up seriously, then it leads to 5D (delays, defects, dissatisfied customers, declining profits, and demoralized employees).

This 5S implementation has to be carried out inphased manner. First the current situation of theworkplace has to be studied by conducting a 5S audit. This audit uses check sheets to evaluate the current situation. This check sheet consists of various parameters to be rated say on a 5-point basis for each 'S'. The ratings give the current situation. The each of the above-mentioned 5S is implemented and audit is conducted at regular intervals to monitor the progress and evaluate the success of implementation. After the completion of implementation of 5S random audits could be conducted using company check sheets to ensure that it is observed in true spirits by everyone in the work place depicts the key activities to be holistically deployed for effective 5S implementation at the workplace.

## V. OEE AND THE SIX BIG LOSSES

OEE (Overall Equipment Effectiveness) is a metric that identifies the percentage of planned production time that is truly productive. It was developed to support TPM initiatives by accurately tracking progress towards achieving "perfect production".

- An OEE score of 100% is perfect production.
- An OEE score of 85% is world class for discrete manufacturers.
- An OEE score of 60% is fairly typical for discrete manufacturers.
- An OEE score of 40% is not uncommon for manufacturers without TPM and/or lean programs.

**Table 2: TPM Goals**

| Component | TPM Goal | Type of Productivity Loss |
|---|---|---|
| Availability | No Stops | Availability takes into account **Availability Loss**, which includes all events that stop planned production for an appreciable length of time Examples include Unplanned Stops (such as breakdowns and other down events) and Planned Stops (such as changeovers). |
| Performance | No Small Stops or Slow Running | Performance takes into account **Performance Loss**, which includes all factors that cause production to operate at less than the maximum possible speed when running. Examples include both Slow Cycles, and Small Stops. |
| Quality | No Defects | Quality takes into account **Quality Loss**, which factors out manufactured pieces that do not meet quality standards, including pieces that require rework. Examples include Production Rejects and Reduced Yield on startup. |

| | | |
|---|---|---|
| OEE | Perfect Production | OEE takes into account all losses (Availability Loss, Performance Loss, and Quality Loss), resulting in a measure of truly productive manufacturing time. |

**Table 3: Six big losses**

| Six Big Losses | OEE Category | Examples | Comments |
|---|---|---|---|
| Unplanned Stops | Availability Loss | Tooling Failure, Unplanned Maintenance, Overheated Bearing, Motor Failure | There is flexibility on where to set the threshold between an Unplanned Stop (Availability Loss) and a Small Stop (Performance Loss). |
| Setup and Adjustments | Availability Loss | Setup/Changeover, Material Shortage, Operator Shortage, Major Adjustment, Warm-Up Time | This loss is often addressed through setup time reduction programs such as SMED (Single-Minute Exchange of Die). |
| Small Stops | Performance Loss | Component Jam, Minor Adjustment, Sensor Blocked, Delivery Blocked, Cleaning/Checking | Typically only includes stops that are less than five minutes and that do not require maintenance personnel. |
| Slow Running | Performance Loss | Incorrect Setting, Equipment Wear, Alignment Problem | Anything that keeps the equipment from running at its theoretical maximum speed. |
| Production Defects | Quality Loss | Scrap, Rework | Rejects during steady-state production. |
| Reduced Yield | Quality Loss | Scrap, Rework | Rejects during warm-up, startup or other early production. |

**TPM program implementation**

TPM is not a quick fix, it can often take between 2 and 5 years to implement fully depending on the size and complexity of your organisation. The most widely adopted framework for adopting TPM is that of the Japan Institute of Plant Maintenance (JIPM) which is based around 9 steps split into three cycles.

**a. Measurement Cycle;**

i. Equipment history and performance analysis: Select one cell or machine and begin to set project objectives such as manning costs, OEE and material savings.Set up a project board for the 9 steps of the project and the team should start to collect all manuals and drawings. Also assemble all historical records regarding manning, performance rates, breakdowns, maintenance, replacements and accidents.

ii. Calculate OEE:Ensure the team is educated in what OEE is and how to perform the OEE Calculation. Set up your OEE display board at the gemba along with graphs for each contributing factor. This step can take several days to a few weeks to gather meaningful data.

iii. Asses the six big losses and set priorities;Review all of the data collected and have the team agree priorities and plans with management. Do not just jump to the lowest OEE, look also at the process cycle time to see if it is within tact time (the demand time of the customer) and if the process is a bottleneck or causing obvious delays.

**b. Condition Cycle**

iv. Critical Assessment: This is where you start to analyze each and every component of the machine, what does it do, how does it do it, why is designed that way and so forth. This is the opportunity for the whole team to fully understand how the machine works in detail.For each critical component identify ideal conditions (pressure, lubrication, temperature etc.) and also how each can be made to deteriorate quicker than it should.Document everything and keep with the machine so that all have access.

v. Cleanup and condition appraisal;

This step is very much like the third stage of 5S Shine apart from it goes into much greater depth. Start by taking pictures of the current state, and then begin to inspect and clean each component filling in an appraisal form to detail any issues. Develop a cleaning program as well as identifying all possible causes of contamination both inside and outside the machine and develop plans to either eliminate, isolate, prevent or if you have to clean.

vi. Planed Refurbishment;

Plan and conduct all refurbishment identified in the previous stages. Also implement any changes to eliminate contamination, introduce pokayoke devices and examine and implement quick changeover through SMED (single minute exchange of die.)

vii. Develop Asset care;

This is the stage which most people identify with TPM, the introduction of autonomous maintenance where the operators themselves undertake daily inspections, lubrication, simple repairs, and simple replacements and detect problems themselves. We also establish visual management using kamisshabi boards to show what work has been done, color code and identify all gauges, pipes, cables etc with reference to the manuals as well as installing inspection windows so you can see what is happening inside the machine.

**c. Problem Prevention Cycle;**

viii. Best practice routines and standards; Just as in the 5S standardization step we develop and implement standard operating methods based on all that we have learned through the previous steps. We develop best practice manuals, single point lessons and spares requirements; all of which are kept with the machines not locked away in an office somewhere.

ix. Problem Prevention:Using our measures of OEE we use the 5 whys and other quality tools to identify solutions and improvements with a preference for low cost and no cost solutions.

## VI. IMPLEMENTATION REPORT IN MAINTANACES DEPARTMENT

'Kaizen' literally means 'change for the betterment'. Kaizen involves small improvements and is carried out on a continual basis and involving people of all level in the organization. The principle behind Kaizen is that 'a very large number of small improvements are more effective in an organizational environment than a few improvements of large value'. This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough procedure we eliminate losses in a systematic method using various Kaizen tools. Objective of Kaizen is achieve and sustain zero loses with respect to minor stops, measurement and adjustments, defects and unavoidable downtime.

**Table 4: Implementation of TPM**

| Before | After |
|---|---|
|  **Unwanted angles and pipesare kept near the window** |   **That much area is used to keep accepted and rejected parts.** |
|  **No labelling is done and tools are placed randomly in racks** |  **Labelling is done and tools are stored in their respective places identified** |
|  **Allen keys, nut bolts and other tools are kept randomly.** |  **Proper places are decided for each tool.** |
|  **No red tag marking is done for rejected materials.** |  **Red tag marking is done and wall is also white washed** |
|  **Plastic bags and waste cotton is randomly kept** |  **They are kept systematically** |
|  **Operators used to spit in Corner after chewing tobacco** |  **Resisted use of tobacco** |

| | |
|---|---|
| **No operator is writing hourly report** |  **Writing hourly report is compulsory** |
| **Employee details are not displayed on the notice board** |  **Employee details are displayed on the notice board** |
| **No working information is displayed on the notice board** |  **Working information is displayed on the notice board** |

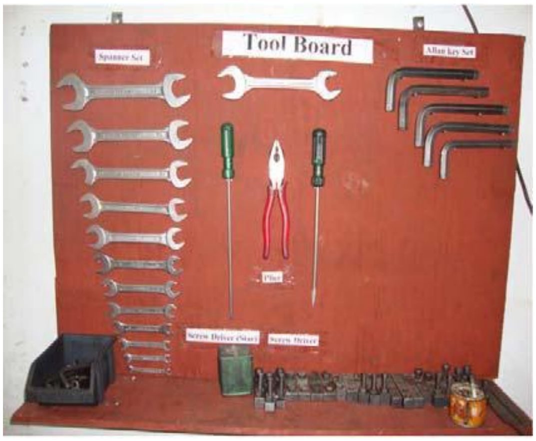


**Figure 4.Implementation of Pokayoke**

## VII. DATA ANALYSIS

Overall Equipment Effectiveness (OEE) is widely use as the measure of success of TPM implementation. Overall Equipment Effectiveness is given as: Availability × Performance Efficiency × Quality Rate ($OEE$ = A × $PE$ × $QR$)[1]. Availability takes into account the losses due to equipment failure and setup and adjustment and is calculated as the ratio of operating time to loading time. Performance Efficiency includes losses due idling and minor stoppages and speed loss and is calculated as ratio of net operating time to operating time. Quality rate factors the defects in process and reduced yield and is defined as ratio of valuable operating time to net operating time. Following table gives the summary of observation made beforeand after TPM implementation.

Availability = Operating time/planned production
Performance = Ideal Cycle Time / Total Pieces
Quality = Good Pieces / Total Pieces
OEE = Availability X Performance X Quality

**Table 5 Implementation of TPM**

| Sr. No. | Category | Before implementation | After implementation |
|---|---|---|---|
| 1 | Shift time | 420 min | 420 min |
| 2 | Total production in a shift | 3200 kg | 3200kg |
| 3 | Scheduled break | 60 min | 60 min |
| 4 | Non-scheduled break | 30 min | 10 min |
| 5 | Operator absent | 30 min | 10 min |
| 6 | Total Time Break | 120 min | 80 min |
| 7 | Time taken per Kg Production | 10.66 min | 9.41 min |
| 8 | Availability ($A$) | 0.71 min | 0.80 min |
| 9 | Performance Efficiency ($PE$) | 1 min | 1 min |
| 10 | Quality Rate ($QR$) | 0.96 | 0.99 |
| 11 | OEE ($A \times PE \times QR$) | 0.66 | 0.79 |

## VIII. RESULT

1. Improved equipment performance eliminates the root cause of defects.
2. Defects are prevented through planned maintenance.
3. Preventive maintenance costs are reduced as equipment operators conduct autonomous maintenance.
4. Improved equipment designs ensure that new equipment naturally produces fewer defects
5. Simplified products designs and a redesigned process produce with few defects

Engineers, technicians and managers are trained in maintenance and quality

## IX. CONCLUSION

Success of TPM depends on various pillars like 5-S, JishuHozen, Planned Maintenance, Quality maintenance, Kaizen, Office TPM and Safety, Health & Environment.Overall Equipment Effectiveness has improved from 66 % to 79% indicating the improvement in productivity and improvement in quality of product.It is observed that most of the defective components are because of the previous process namely casting hence to improve the productivity efforts must also be given to previous process as well.The key factors for this implementation are workers involvement and top management support. Still world class TPM implementation is possible with continual support at all the levels along with the supply of necessary resources.

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